Mean field studies for the Pt isotopes

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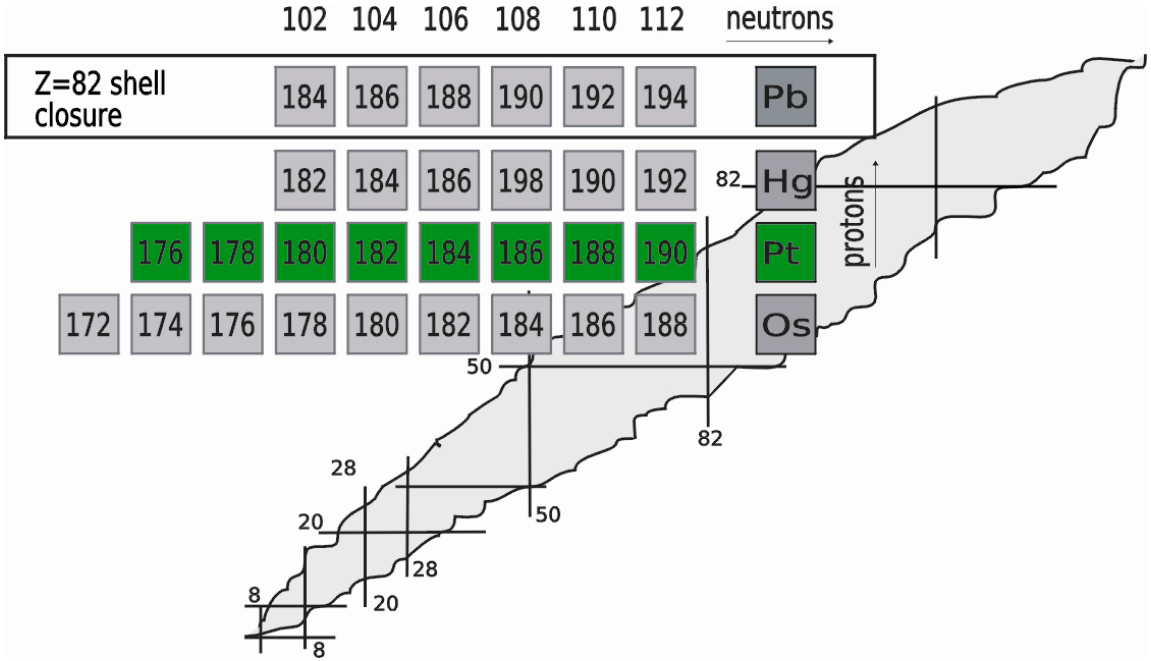
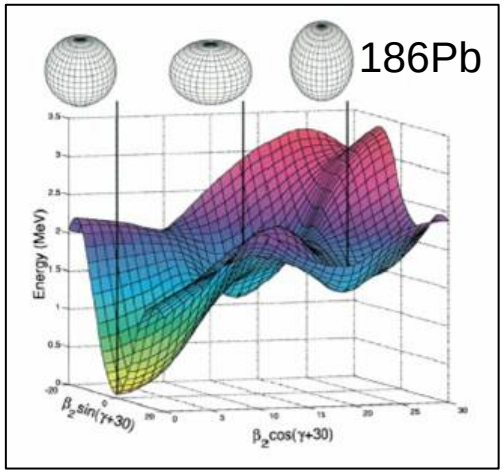
1:: Introduction

Why the Pt isotopes?



The Z=82 region is 'famous'

because of the occurence of shape coexistence



A.N. Andreyev, Nature

→ in the Pt-isotopes a sudden drop in the energy of the $0^+(2)$ state is observed around neutron midshell
→isotopic shift measurements display a sharp change in the nuclear charge radius
→ is considered as a transitional region : transition from a prolate to an oblate minimum when going from lighter neutron-deficient Pt isotopes to the heavier ones.

2:: Mean-field calculations for the even Pt

Hartree-Fock method

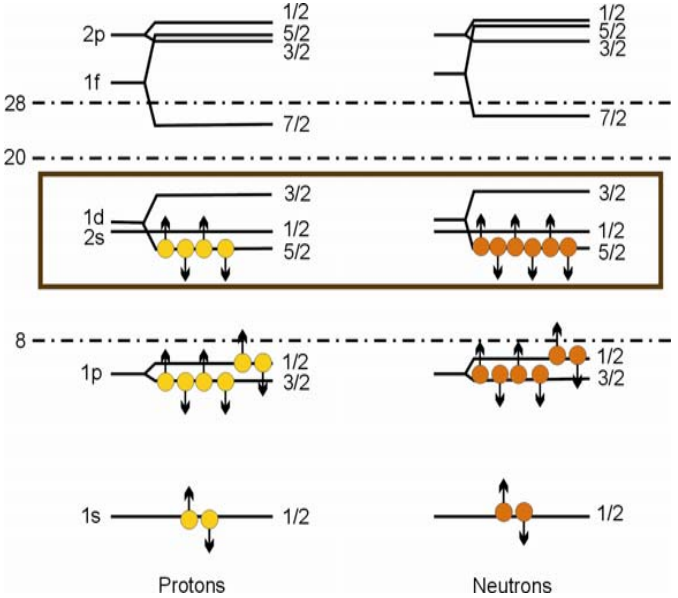
basic ideas : 1/ the success of the nuclear shell model

justifies the assumption that the nucleons

move fairly independently in an avarage potential

$$\hat{H}^{HF} = \sum_{i=1}^{A} \hat{h}(i)$$

$$|HF\rangle = \prod_{i=1}^{A} a_i^{\dagger}|-\rangle$$



2/ solving the Schrödinger equation $\hat{H}|\Psi\rangle = E|\Psi\rangle$

is equivalent to solving the variational equation $\delta \frac{\langle\Psi|\hat{H}|\Psi\rangle}{\langle\Psi|\Psi\rangle} = 0$

HF equations are obtained when one obliges the wavefunction $|\Psi\rangle$ to be a Slater determinant during the variation $\delta \frac{\langle \Psi | \hat{H} | \Psi \rangle}{\langle \Psi | \Psi \rangle} = 0$

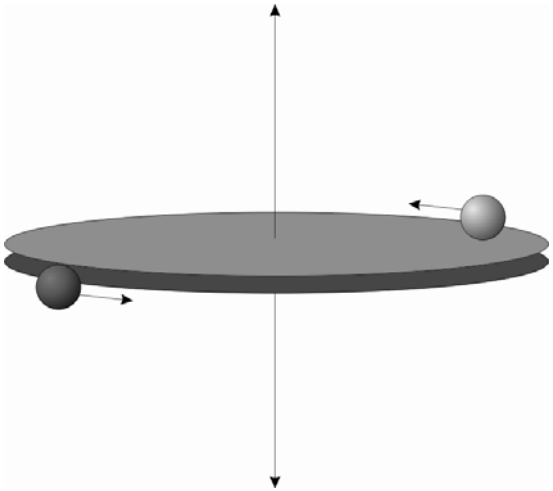
Hartree-Fock plus BCS

The pairing force

$$\hat{H}_{pair} = \sum_{k,k'>0} \bar{v}_{k\bar{k}k'\bar{k}'} a_k^\dagger a_{\bar{k}}^\dagger a_{\bar{k}'} a_{k'}$$

$$|k\rangle \rightarrow |j,m\rangle$$
$$|\bar{k}\rangle \rightarrow |j,-m\rangle$$

energetically favours the coupling of two nucleons to J=0



For the description of pairing between particles moving in different non-degenerate orbitals, one introduces the **Boguliubov quasi-particles**

$$\alpha_k^\dagger = u_k a_k^\dagger - v_k a_{\bar{k}} \qquad \alpha_{\bar{k}}^\dagger = u_k a_{\bar{k}}^\dagger + v_k a_k$$

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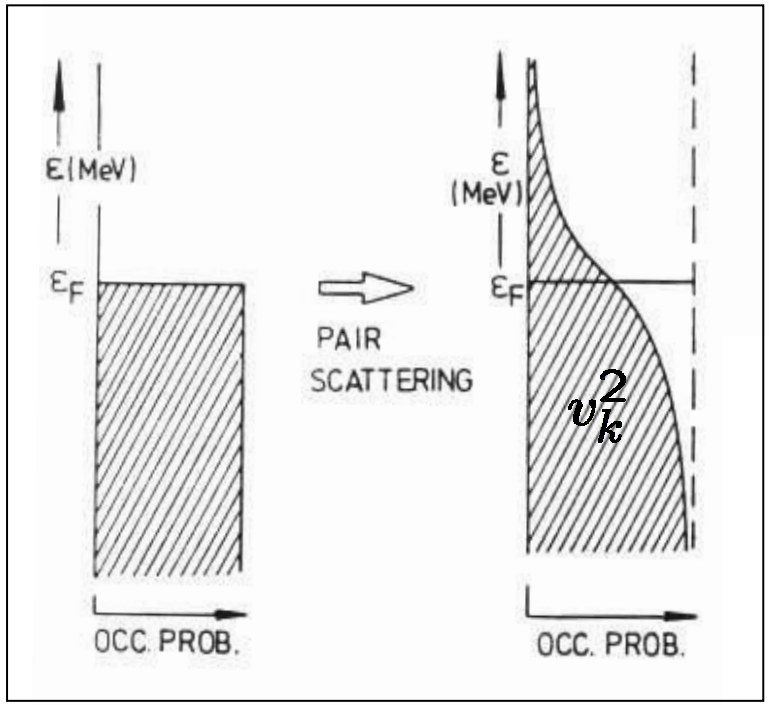
- some properties of a hole, some properties of a particle
- transformation does not conserve particle number!!

➔ wavefunction for even-even nuclei? $|BCS\rangle \propto \prod_k \alpha_k |-\rangle$



K. Heyde, The nuclear shell model

i.e. a gas of non-interacting quasiparticles

➔ BCS equations follow from the variation of

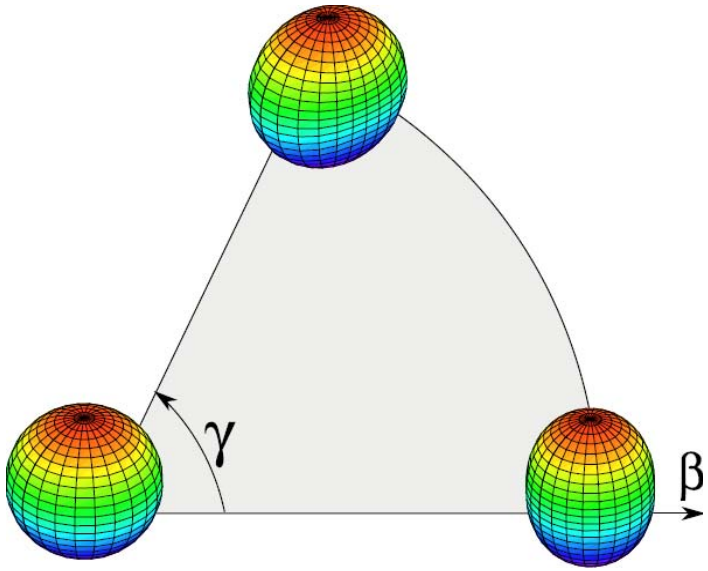
$$\langle BCS|\hat{H} - \lambda\hat{N}|BCS\rangle$$

enforce correct average particle number

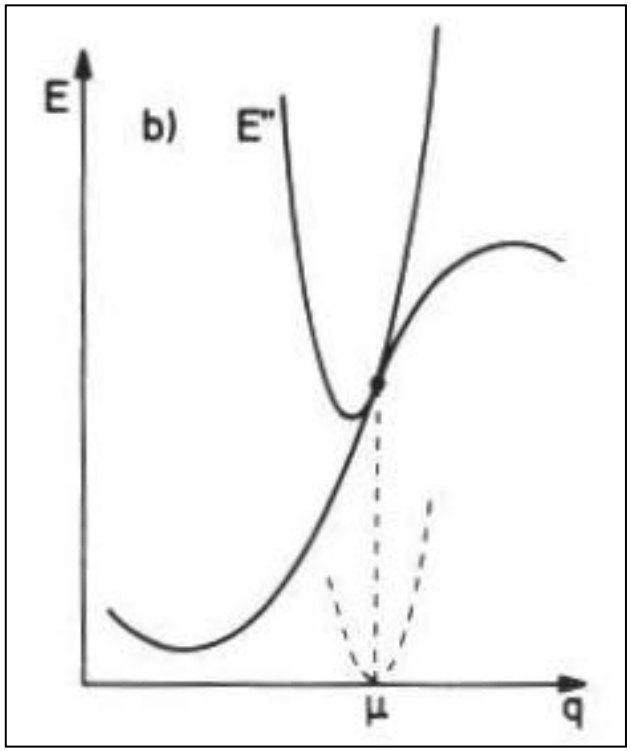
Constrained HF +BCS

HF searches the minimum of the energy surface

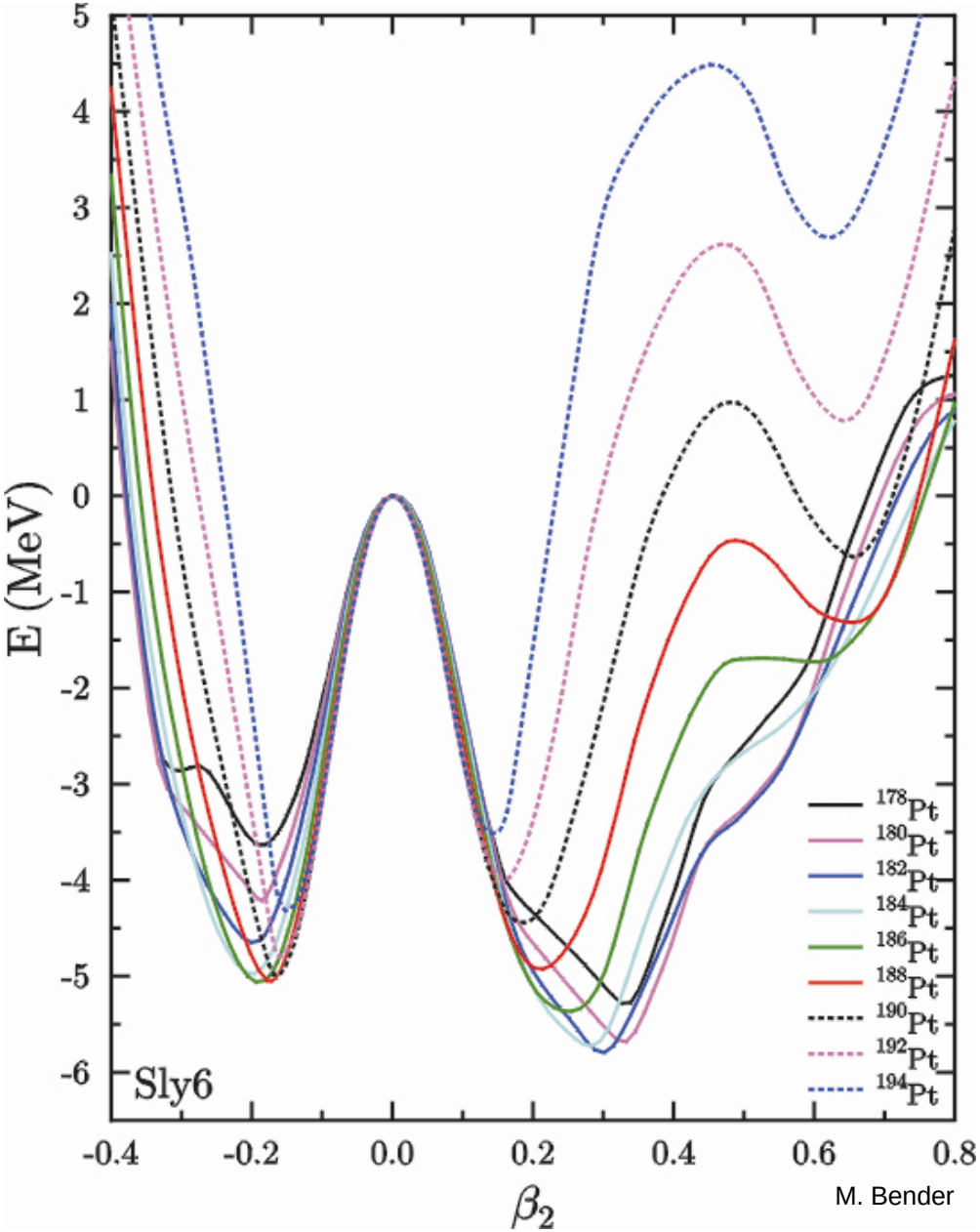
➔ evolution of the energy with changing deformation?



$$\langle \Psi | \hat{H}'' | \Psi \rangle = \langle \Psi | \hat{H} | \Psi \rangle + \frac{1}{2} C (\langle \Psi | \hat{Q} | \Psi \rangle - \mu)^2$$



- β axial quadrupole deformation
- γ non-axial quadrupole deformation



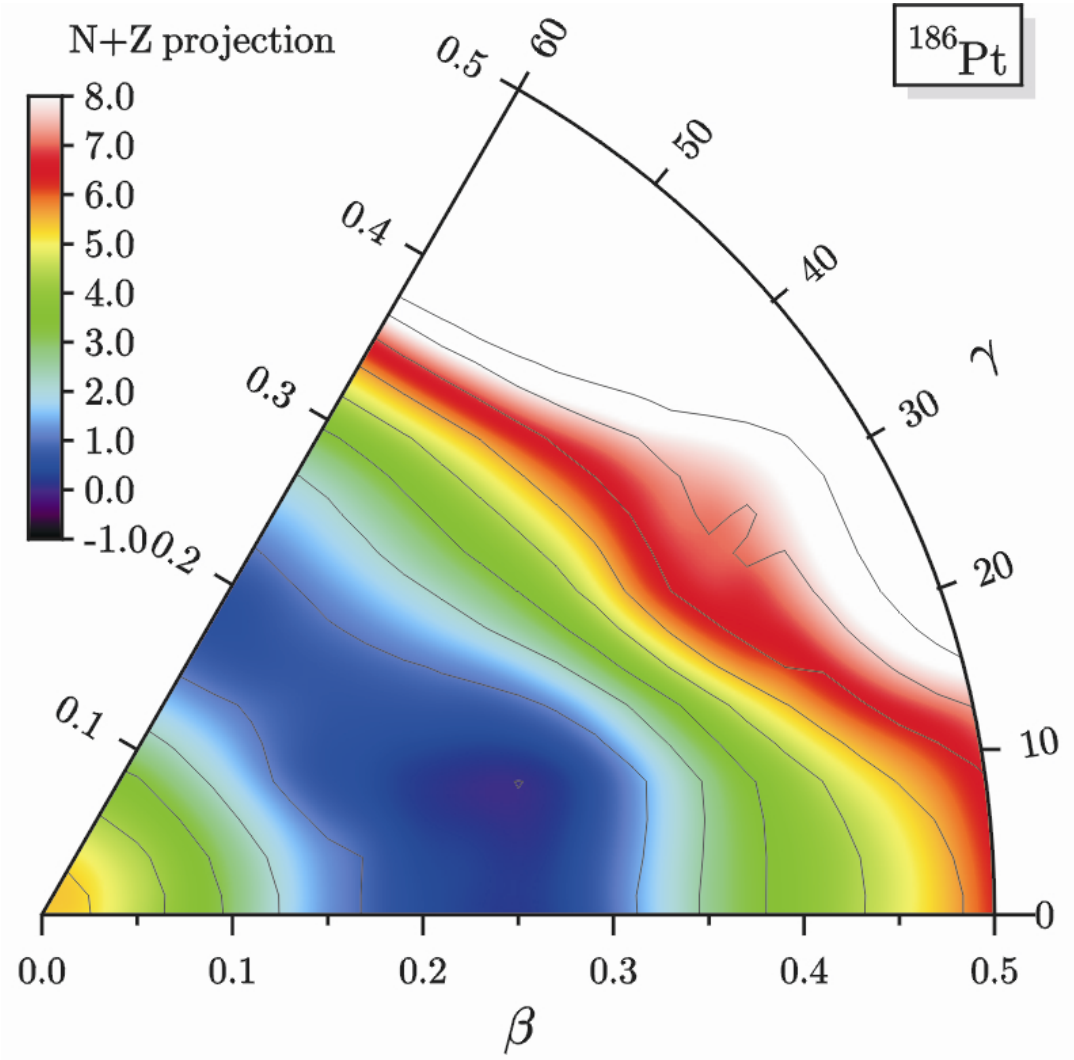
HF+BCS+LN

SLy6

pairing strength -1250 MeV

- transition from prolate to oblate minimum in the β direction with increasing N
- strongly deformed prolate minimum for the lighter Pt
- in 188Pt, the minima are nearly degenerate

→ what about the γ-direction?

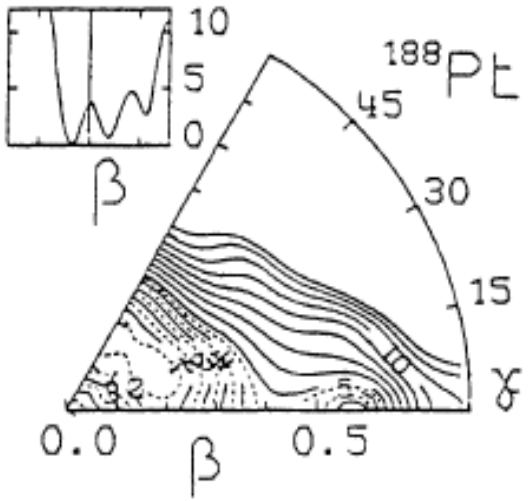


HF+BCS+LN

SLy6

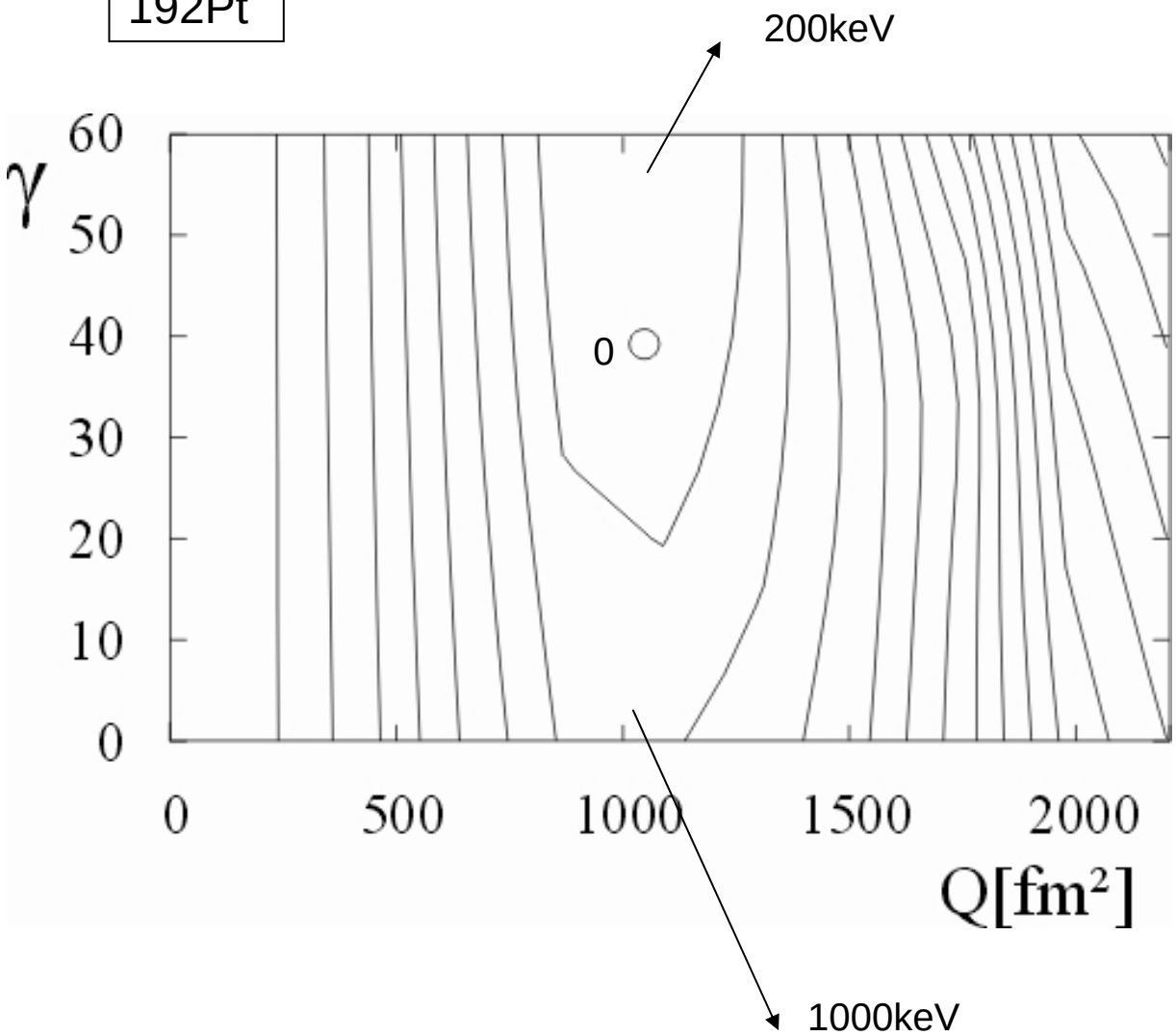
pairing strength -1250 MeV

slightly triaxial minimum



M. Girod et al, PRL 62 (1989),2452

192Pt



HF+BCS+LN

SLy6

pairing strength -1250 MeV

3:: Mean-field calculations for the odd Pt

Hartree-Fock + BCS

$$\alpha_k^\dagger = u_k a_k^\dagger - v_k a_{\bar{k}}$$ quasi-particle

$$|BCS\rangle \propto \prod_k \alpha_k |-\rangle$$

➔ thus : the basic building blocks of the quasiparticle with quantumnumber k are the conjugate states k and $\bar{k}$

Hartree Fock Boguliubov

natural extension of the BCS quasi-particles :

$$\beta_k^\dagger = \sum_l U_{lk} c_l^\dagger + V_{lk} c_l$$

transformation defined over all particle operators, NOT only the conjugate states

HFB equations follow from

$$\delta \frac{\langle \Phi | \hat{H} | \Phi \rangle}{\langle \Phi | \Phi \rangle} = 0$$

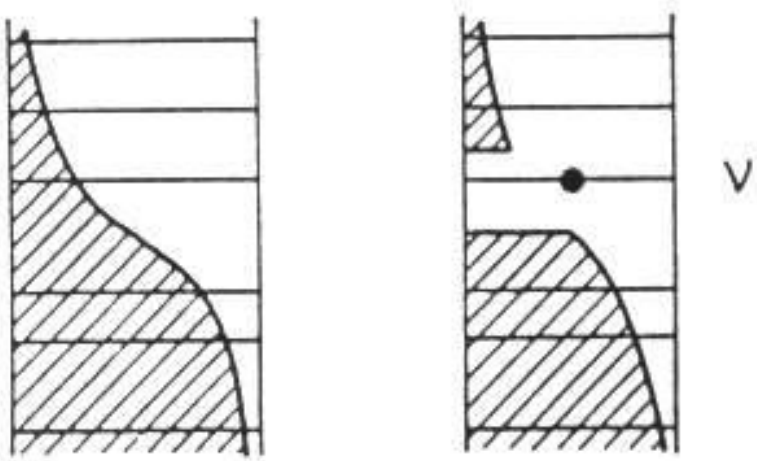
with $|\Phi\rangle = \prod_{k=1} \beta_k |-\rangle$

Odd nuclei ?

→ in HF+BCS odd nuclei can be described with one-quasiparticle excitations

$$\alpha_{k_1}^{\dagger}|BCS\rangle = a_{k_1}^{\dagger} \prod_{k \neq k_1} \alpha_k |-\rangle$$

➔ a certain single particle state is blocked



→ in HFB one quasi-particle states are defined similarly

$$|\Phi_l\rangle = \beta_l^{\dagger}|\Phi\rangle = \beta_l^{\dagger} \prod_k \beta_k |-\rangle$$

➔ the structure of the blocked qp is more general than in BCS

How do we introduce rotational motion?

variation with subsidiary condition that the angular momentum operator Jx has a certain expectation value (x-axis is not the symmetry axis)

$$\delta\langle\Phi|H - c(J_x - \bar{J}_x)^2|\Phi\rangle = 0$$

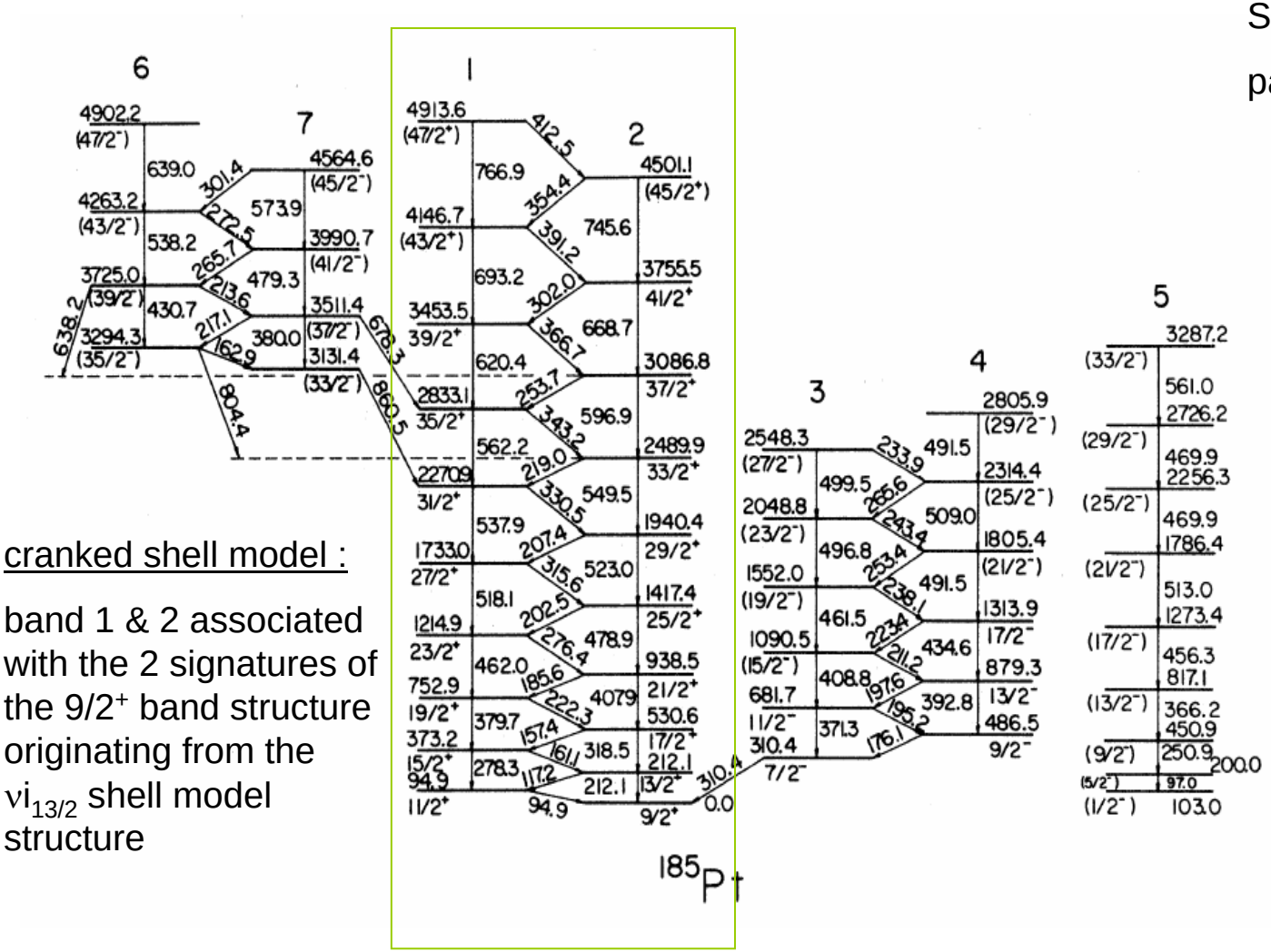
185Pt

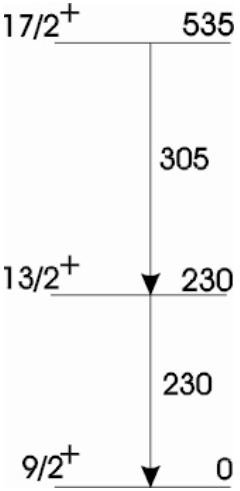
HFB

SLy6

pairing strength -1250 MeV

1 neutron qp excitation (starting from 186Pt) with prolate deformation and K=-9/2, parity +1 and signature -1





cranked shell model :

band 1 & 2 associated with the 2 signatures of the $9/2^+$ band structure originating from the $\nu i_{13/2}$ shell model structure

S. Pilotte et al, PRC (1989) 610

193Pt

HFB

SLy4

pairing strength -1250 MeV

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States in ^{193}Pt using the (p,t) reaction

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(Received 16 April 1979)

goes to any other state. Thus the $\frac{1}{2}^-$ ground state of ^{193}Pt can be qualitatively identified as the band head of the $\frac{1}{2}^-|530|$ Nilsson state arising from an oblate potential with, however, considerable rotation-particle and vibration-rotation coupling. Reasonable but very tentative higher rotational members of the $\frac{1}{2}^-|530|$ band are the possible $\frac{3}{2}^-$ state at 188 keV and the $\frac{3}{2}^-$ or $\frac{5}{2}^-$ state at 232 keV assumed here to be $\frac{5}{2}^-$.

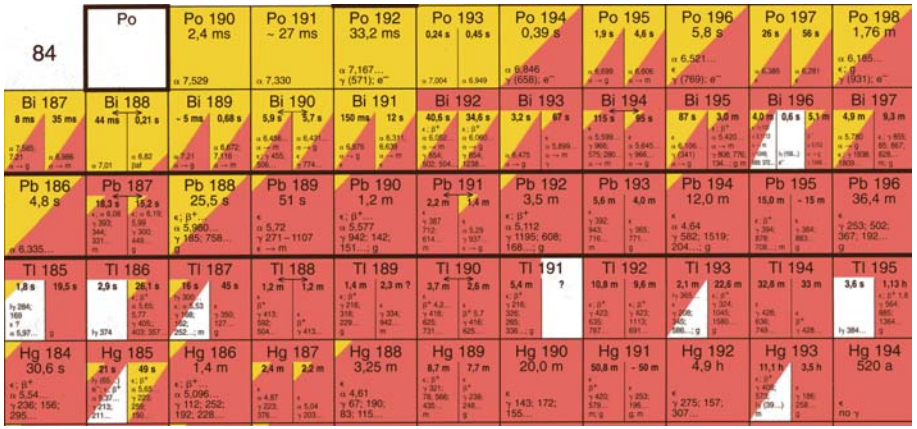
1 neutron qp excitation (starting from 192Pt) with oblate deformation and K=-1/2, parity -1 and signature -1

⟶ with cranking, we obtain a 5/2- state at 255 keV

experimental B.E. : 1531.218 MeV
B.E. of 1/2- state : 1527.850 MeV

4:: Outlook

- We have properly converged wavefunctions for some even and odd Pt-isotopes. These can be used as an starting point for other calculations in the Z=82 region, such as Hg, Po, Os, etc.



- Include the tensor part of the skyrme interaction in the HFB+ cranking code
- Study the effect of the time-odd components in the skyrme energy density functional